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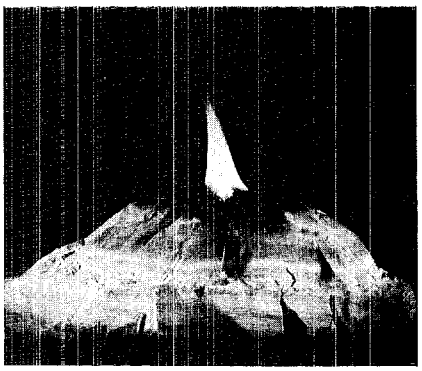
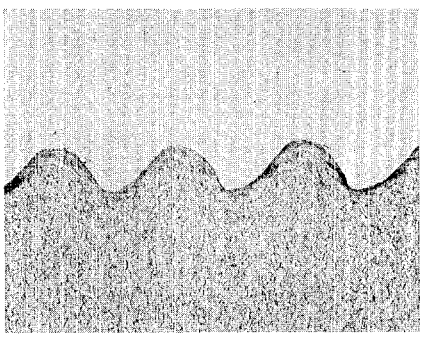
ON THE COVER:
Rock can burn, especially if it contains enough oil shale. LeRoy N. Sanchez photographed this rock sample, which burned on its own after it had been ignited with a torch. Other photographs and a story on the prospects of oil shale recovery follow inside.





Preview:

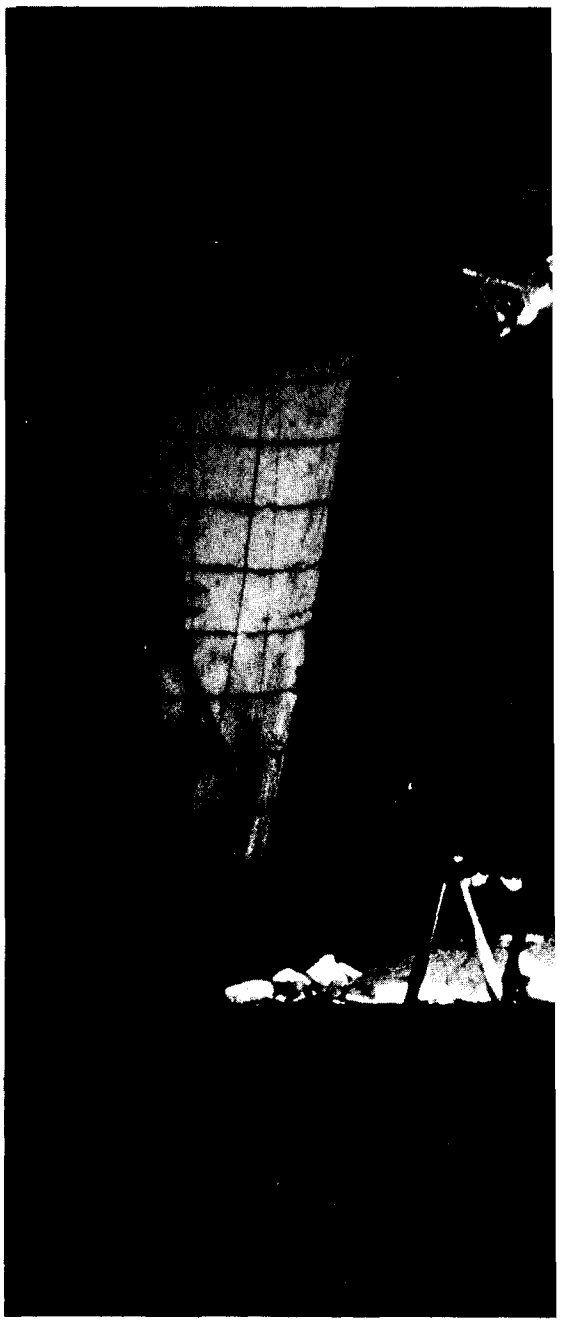
There is a lot of oil in U.S. shale deposits, but don't think you can mine a trunkful and start running your car on it yet; experts say it will be many years before an oil shale industry begins operating in the West. A LASL group conducted two underground shale fracturing tests in late March, with an eye toward verifying their computer models of shale formations. A report on their progress at the Colony Mine, northwest of Grand Valley, Colorado, leads off in this issue...

One LASL group, E-2, offers fast turn-around times and a diversity of products that includes printing wiring circuits and cables. When a number of boards is to be drilled, E-2 may turn to the new $60,000 air-driven drill. It is tied to a computer and each drilling operation is reproduced according to a master photographic negative. The cable shop at E-2 can twist up to 40 kinds of wire or packing for custom orders...

Mention welding and most people think of arcs, filler rods, and a spray of sparks. There is, however, another form to this art, one not so well known to the layman. It's called explosion welding, and it means two metal plates are joined to each other from the force of a blast. A.A. Popoff has worked with metals and explosives for some 15 years and has helped fabricate some exotic parts at LASL...

Floodlights helped video cameras record the results of the first underground explosion March 28. The Colony Mine was the scene of oil shale research mining from 1964 to 1972. Note the steel bolts in the ceiling; mine officials say no movement has been detected in years.

Photos by LeRoy N. Sanchez



Unlocking oil shale: ace in the hole?

By Jeff Pederson

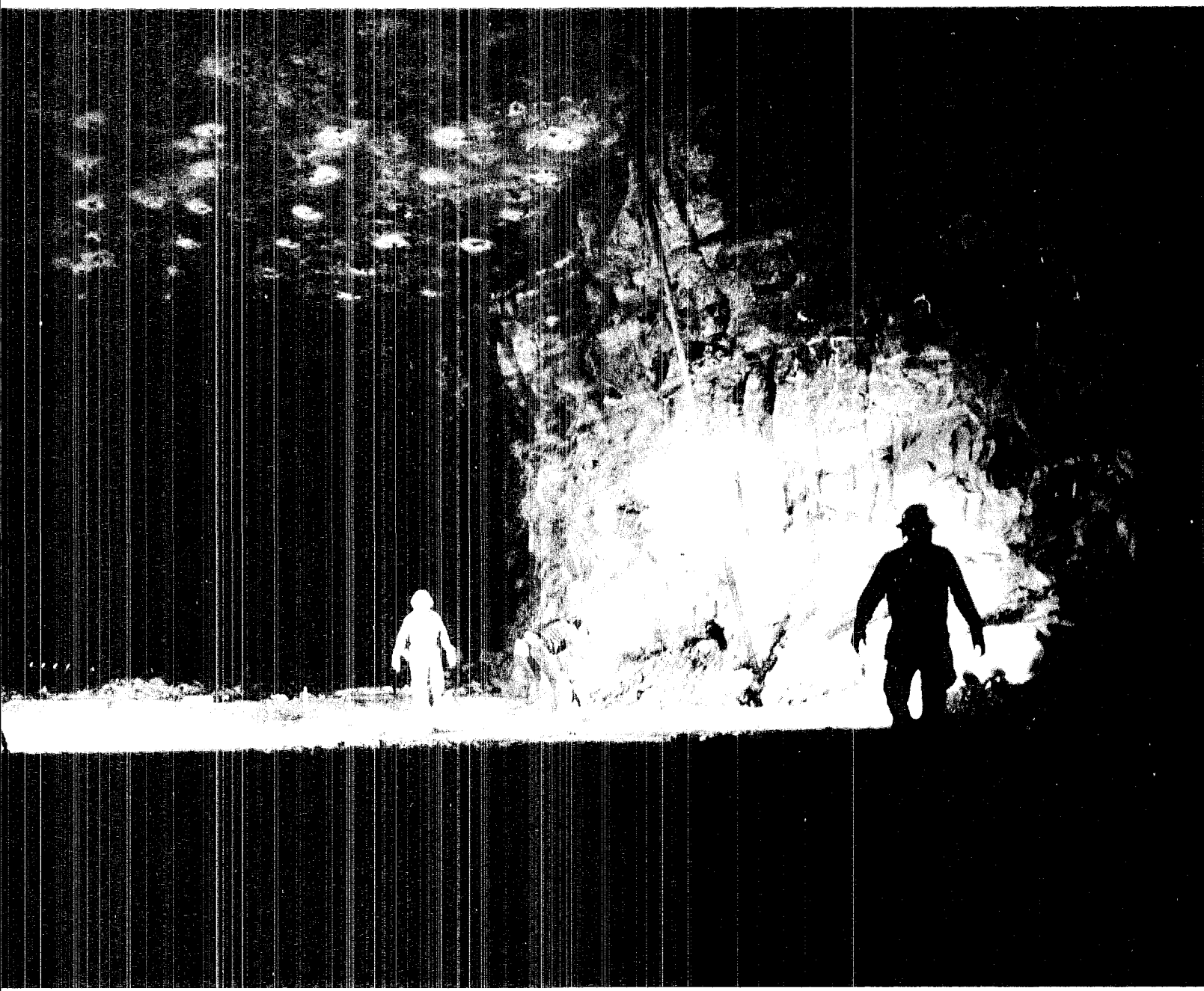
About 50 million years ago, in the Eocene epoch, a shallow lake formed where Colorado, Utah and Wyoming now meet. Snow melted during thousands of springtimes on distant highlands, bringing carbonates and other materials to the placid, slightly alkaline lake.

Over thousands of seasons, algae bloomed, died, and decayed in this environment. What was left and later compressed became transformed into substances that contain hydrocarbons. These were locked into rock strata that were later uplifed in the present day Green River shale formation.

Today, it is possible to follow these strata for hundreds of miles. This "oil shale" contains between a few gallons and up to 65 gallons of shale oil per ton. At places, the strata outcrop in dramatic rock bluffs, exposing to the elements what is increasingly termed a national treasure.

A well-circulated story tells of a homesteader who built his cabin fireplace, unknowingly, out of oil shale rock. When he lit his first fire, he lost his home in the ensuing blaze.

There is reason to believe the Indians who inhabited the Green River basin before the homestead era also knew that oil shale was special rock. Today, the oil companies are also aware, and have



staked claims in the name of Atlantic Richfield, Union Oil, Occidental Petroleum, Standard Oil, and others.

And as crude oil becomes an ever more precious commodity, the Department of Energy's interest has also picked up. In late March at the Colony Mine (a site that borders U.S. Naval Reserve 1), scientists from LASL conducted the first in a series of carefully instrumented field tests. Their goal is to see how oil shale can be fractured below the surface to economically produce petroleum, in a method tolerated by the environment.

At stake is an estimated 2 trillion barrels of oil, enough to last the country at least 100 years at present consumption rates; or an amount equal to the proven reserves of Saudi Arabia.

First test

It is an eerie and airy feeling to walk into the Colony Mine. Now owned by Atlantic Richfield and Tosco Corp., it was mined experimentally from 1964 to 1972, and exists as a series of large rooms and hallways. Corridors are typically 30 feet high and 50 feet wide from rib to rib (wall to wall). The site is 16 miles northwest of Grand Valley, up Parachute creek from the Colorado River.

A small group of experimenters and interested media representatives crowded around the main con-

At Colony Mine field tests, LASL was trying to gather data to confirm computer models it is developing for oil shale recovery.

trol panel about noon March 28. Following some technical delays, the blast in the mine's floor was set for 3 p.m.

An explosive cap was test-fired first, to check the circuitry, and its brief report was followed by the installation of foam earplugs by everyone present. Growling stomachs, caused by lunch long missed, were forgotten in the final waiting moments.

The countdown was followed by the final connection at the control board. A light tremor was felt underfoot and a boom echoed down the giant dark corridors. A dust cloud, spawned by the explosion, showed on the video monitors.

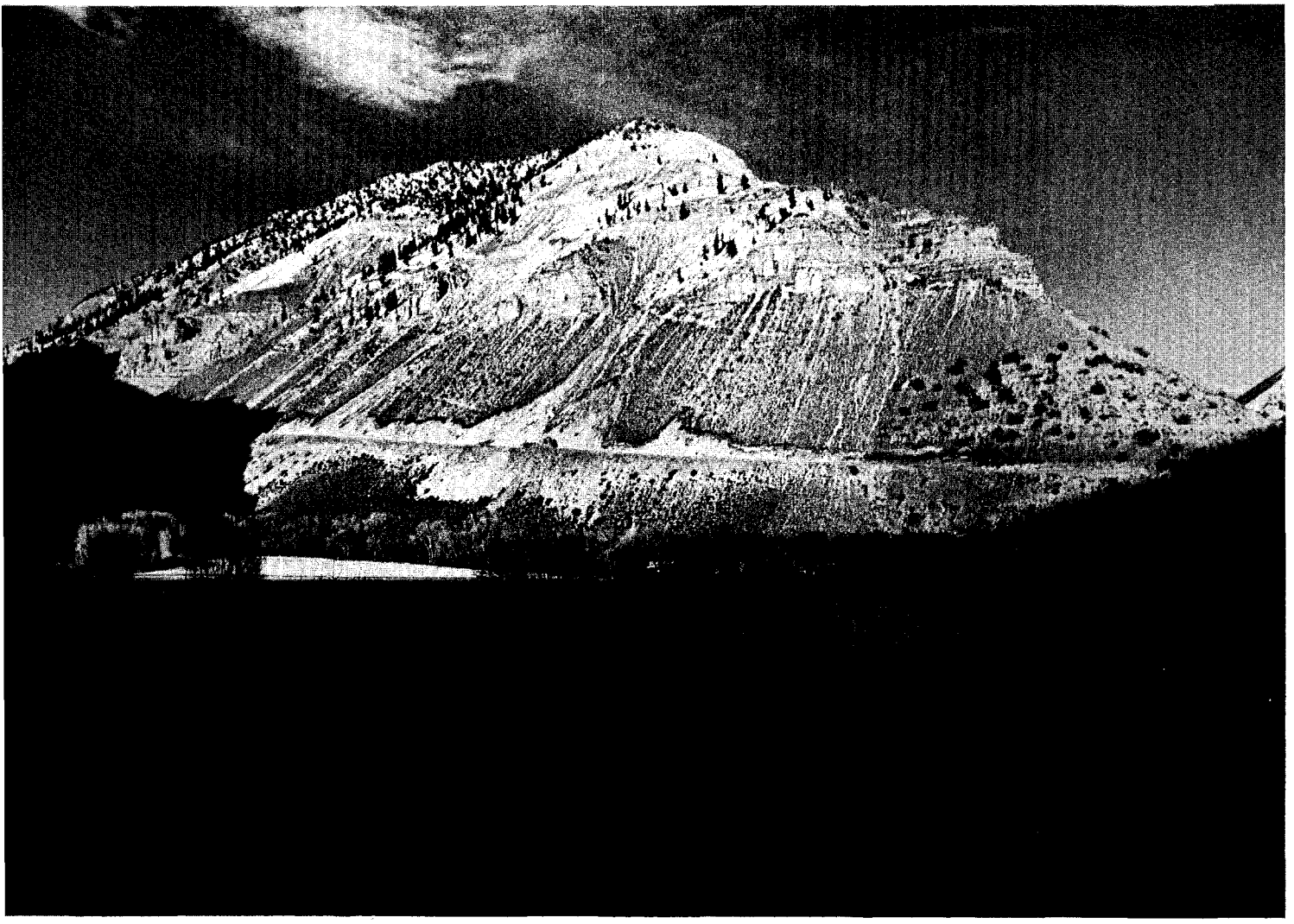
Then a much louder noise was heard as the ventilation fans began to exhaust dust from the test area. After the room had been aired and checked for safety conditions, researchers entered to inspect their work.

To the layman, the only tangible evidence was a faint sulphur-like smell, a light haze in the air, and a few chunks of loose rock broken from the mine floor.

It was enough.

"We've been looking forward to this for a long time," said W.J. Carter, leader of the *In Situ* Science (G-7) group.

"C.L. Edwards (assistant group leader and principal investigator)



Parachute Creek valley, site of the Colony Mine, features grazing and agricultural lands along the waterway, beneath steep rock outcroppings. At the base of the hill in background is a road built by an energy company as part of its oil shale exploration in the Piceance Creek basin.

got a good shot. He got a lot of data out of this," said Phil Wapner, a LASL industrial staff member from Gulf Oil who is involved with the project.

"We're real pleased," said Mike Ray of G-7, as he bent to examine a fracture that had carried several feet into a nearby fracture, one created from a previous pilot test in the shale.

At least part of the blast site will be excavated, and part will be studied with core samples. It will be two months or so before detailed analyses are final, said Carter, but G-7 planned at presstime to present preliminary findings at an April 19 oil shale symposium in Golden, Colorado.

LASL in the field

Many persons at LASL, with help from Sandia Laboratories and EG&G, worked long hours in preparing for the underground explosion tests March 28 and 30.

Using expertise in explosives, material properties, hydrodynamics, and geology, members of group G-7 are gathering data to refine and calibrate computer models that can predict fracture properties of shale under explosion loading.

To that end, Edwards supervised the placement of instruments and 200 pounds of explosives into holes drilled into the mine cavity. ANFO, or ammonium nitrate and fuel oil, was packed into a borehole from 28 feet below the floor up to a 10 foot depth. The test March 28 was in the mine floor, vertical to the plane of shale. The March 30 test was in the mine wall, parallel to the shale bed. Each test fractured rock; the first test did not displace shale but the second test created rubble in the corridor.

In all, 109 separate diagnostic tests were conducted with each blast. Instruments were placed in four- and six-inch diameter holes around the explosive charges, and they relayed information simultaneously to an elaborately equipped mobile laboratory some 500 feet away in the Colony Mine.

Floodlights were set up in the test room to provide illumination for the video camera that would give G-7 instant replay of the ground motion at detonation time. Seemingly incongruous, considering the scientific nature of the tests, were two rows of shiny tin cans among the trails of diagnostic wires. The cans' movement, as captured on video tape and by high-speed cameras, would also help tell the story of the initial surface motion when the blast occurred.

Before the tests, acoustic scanning, coring, and extensive geologic studies were performed. These showed where fractures and joints lay, and provided information about the shale's naturally occurring features.

During the explosions, particle velocities and rock stresses were measured against time. On video tape, on motion picture film, on computer memory, and on analog tape, data were recorded in the mobile laboratory. The information would later be analyzed and interpreted in Los Alamos.

After the tests, fractures and particle sizes were being measured again to gauge before-and-after results. Physical sifting of fragments, along with a mine-back inspection, is being carried out.

The Colony Mine

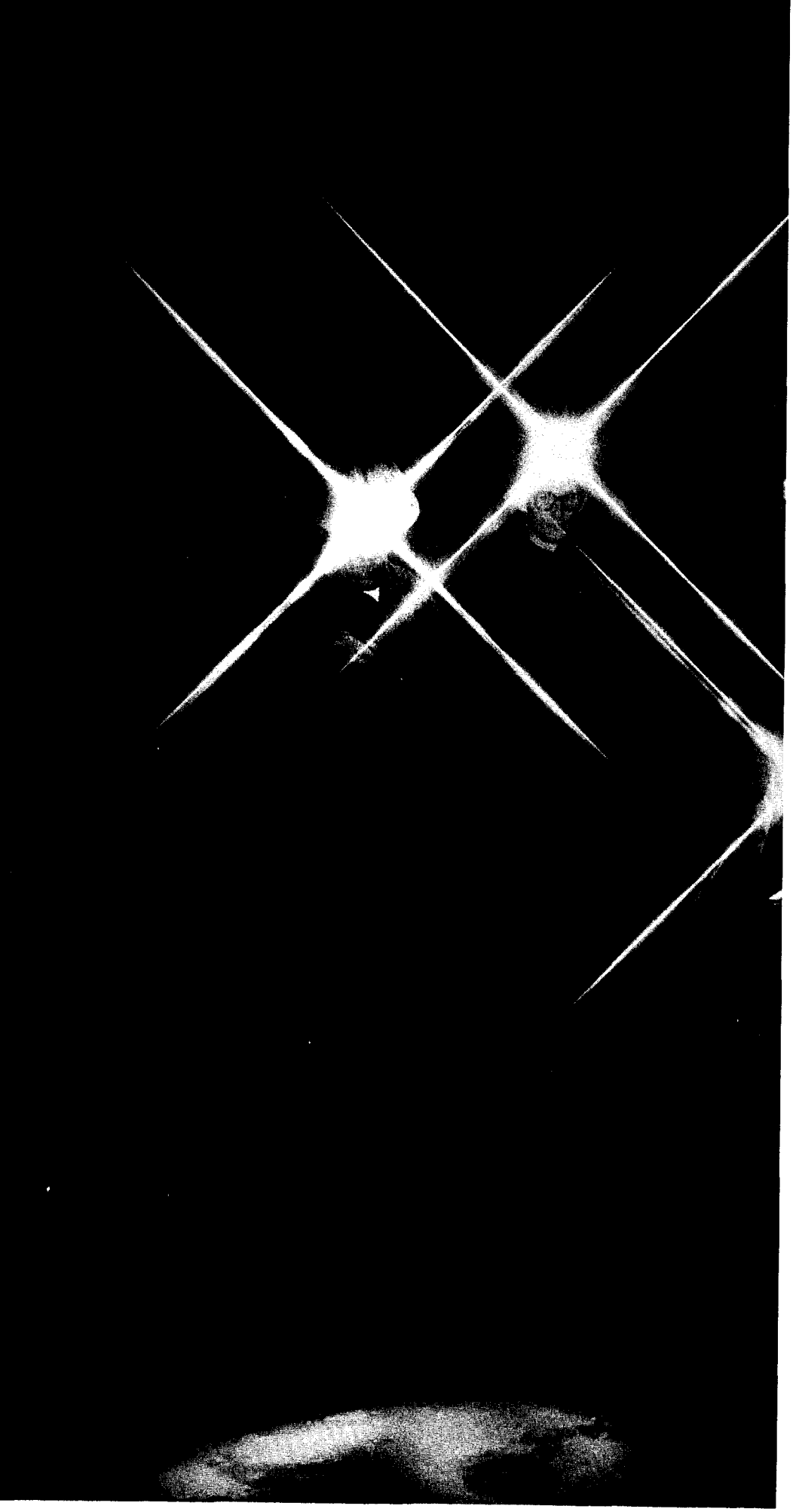
The Colony Mine is situated in one of the major sections of the Green River shale formation, the Piceance Creek basin of western Colorado. Other shale deposits in significant amounts lie in the Uinta basin of eastern Utah and the Green River basin of southwestern Wyoming.

Any large-scale mining operations in the Piceance Creek basin must not only deal with tailings disposal, but with the largest migratory herd of deer in the continental United States. At the Colony Mine, guard Norm Morrison has induced a family of mule deer to eat out of his hand; the animals may not be as accommodating with a series of oil shale plants in the area, and environmentalists want to make sure they are protected.

Mine captain Ki Bianchi, with 45 years' experience behind him, points to the spotless safety record

A large herd of migratory mule deer is of concern to conservationists in oil shale country. Mine guard Norm Morrison has induced a family, including two apparent orphans, to eat from his hand.

50 million years ago, algae bloomed and died on a shallow lake. They eventually were transformed into an oil-like substance, now enclosed in shale rock. The western U.S. has as much of this oil as Saudi Arabia has proven oil reserves.



The 'mahogany zone' of the richest shale is the level of the Colony Mine. The seam runs about 60 feet thick and outcrops to the surface at places.

of the Colony Mine during its years of operation, 1964-72. In this area of the Piceance Creek basin, the richest shale bed, called the "mahogany zone," lies from 400 to 800 feet below the surface, depending from where one measures from the undulating terrain above the mine.

At the Colony Mine, experimental extraction has dealt with taking out both a 30-foot-high seam and the full 60-foot seam of rich oil shale, rock that Bianchi described as "rubbery." In either case, wide pillars are left to support the roof; the floor and ceiling are nearly level as they are, virtually, the shale seam boundary. Steel rock bolts 12 feet long are spaced every five feet to support the ceiling. Even underground nuclear tests at nearby Rulison, conducted in years past by LASL to stimulate natural gas production, have failed to shift the underground strata, said Bianchi.

To the uninitiated, the Colony Mine seems vast. It measures 1,200 feet square. But if it were a commercial mine, that would only represent a two week operation for shale recovery.

Tosco holds a patent on an above-ground retort operation, which used finely crushed shale taken from the mine to produce oil. Atlantic Richfield spokesman Harold Craige said Arco's present position was, "Wait and see." It would take between three and five

Head lamps illuminated a dark section of the mine for researchers. Safety dictates every person going into the mine wear also a self-rescuer breathing unit, in case of accident.

years to bring a shale system online, he said, but it would be 10 years if Arco were starting from scratch. An entirely new shale industry could not be functioning until 1990, he said, if it were begun today.

Craige also said the proposed $3 per barrel risk-sharing package with the government would be helpful, but wouldn't be enough of an incentive to trigger an industry. In 1964, Arco figured it could start a shale plant for $110 million. Today, it would take 10 times that amount.

Except for a skeleton crew, the Colony Mine remains idle.

Watch for vugs

Many pitfalls await the unwary theorist when he moves to the field. Shale researchers have found that "vugs" can be one of their most unpredictable enemies, for instance. While it has been suggested that vugs stand for "voids underground," it can't be proven; but that's what they are.

One possible explanation for vugs' origins is this: when the shale material was laid down millions of years ago, certain mineral deposits wer left in pockets or bands. As ground water leached these pockets away, the result was often vugs.

When LASL packs a test explosion area, workers must try to fill the vugs with a special rock-matching grout. Otherwise, if the rock's makeup cannot be approximated with this cement-and-gypsum mixture, test results can be misleading or unusable as the shock wave is "soaked up" by the vugs.

"We tried to fill the lower part of one hole," said Mike Harper of G-7, "with grout to match the rock. But the grout kept flowing through the hole into the vugs."

The vugs sometimes contain minerals such as calcium carbonate. Ki Bianchi likes to point to a particular vug, 20 feet up on the wall of the mine, and tell visitors it basically is bicarbonate of soda.

"Monday mornings, when the workers are still hung over, we go up there and lick that vug," he jokes. "Years of that is what makes it look so white."

Just how much trouble the vugs will continue to cause, however, is not totally known as LASL works toward its 1981 Department of Energy deadline.

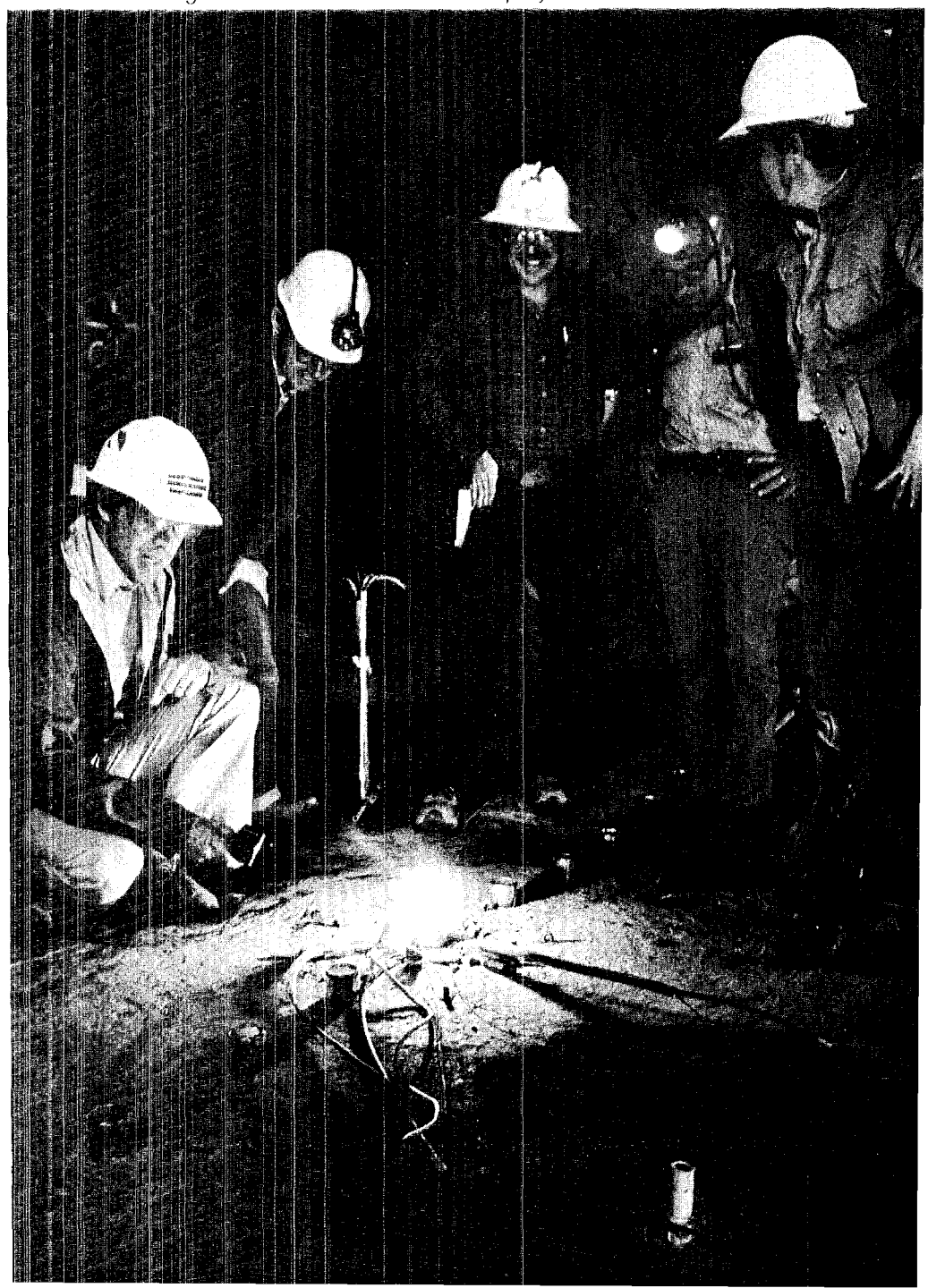
The vugs will probably be overshadowed by greater political and economic considerations in the next decade, as present oil sources diminish and the price of imported petroleum rises.

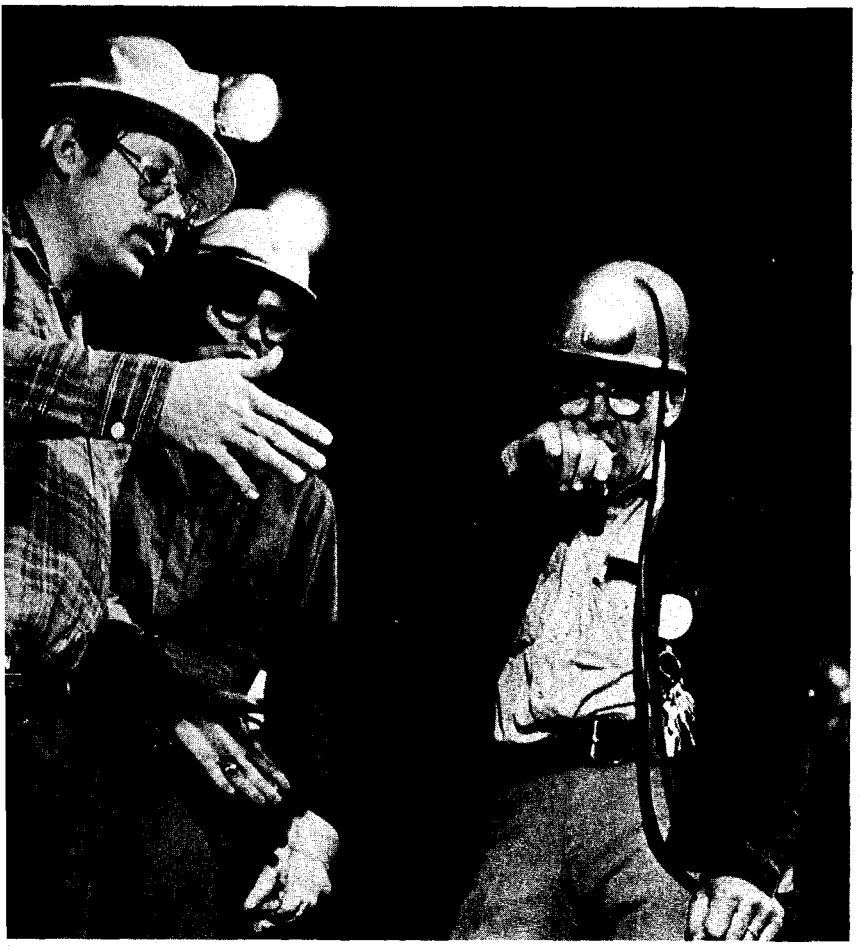
Rocks in the computer

Using computer codes to model the breakup of shale rock will play a vital role in the development of oil shale technology. Models allow the study of changing conditions, such as the amount and type of explosive, without having to run a new and expensive set of field tests.

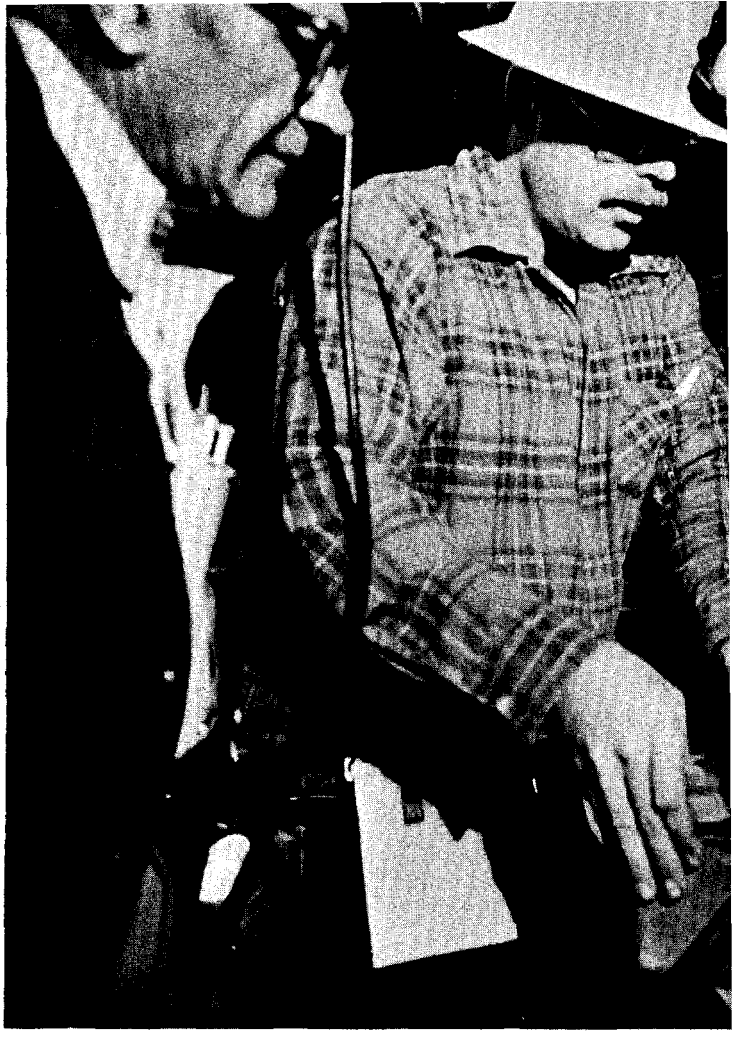
The tests at the Colony Mine, in turn, play a major role in calibrat-

Before detonation, the borehole containing 200 pounds of explosives was checked by W.J. Carter, Mike Ray, C.L. Hunter, Ki Bianchi, and Phil Wapner. Row of tin cans will move when explosive is fired, thus giving researchers an extra look at ground movement on video replay.





Will the blast produce the desired result? C.L. Edwards told Mike Ray and Ki Bianchi that a crater may be produced from the explosion.



Zero time: a slight ground panied by a muffled report, the explosion is shown on

The final connection followed the countdown. A light tremor was felt underfoot and a boom echoed down the giant dark corridors, and the test threw up a cloud of dust on the video monitors.

ing and refining the computer models. Whether oil shale has preexisting flaws that can be opened by the explosive is one example of a fundamental question that can only be answered in the field.

The effort to model oil shale fractures is one that draws on the expertise uniquely available at LASL. Many of the computer codes and techniques were developed originally for other applications, such as the study of nuclear fireballs and nuclear containment at the Nevada Test Site. Knowledge of numerical hydrodynamics, material response to stress, and explosive characterization is being focused now on shale.

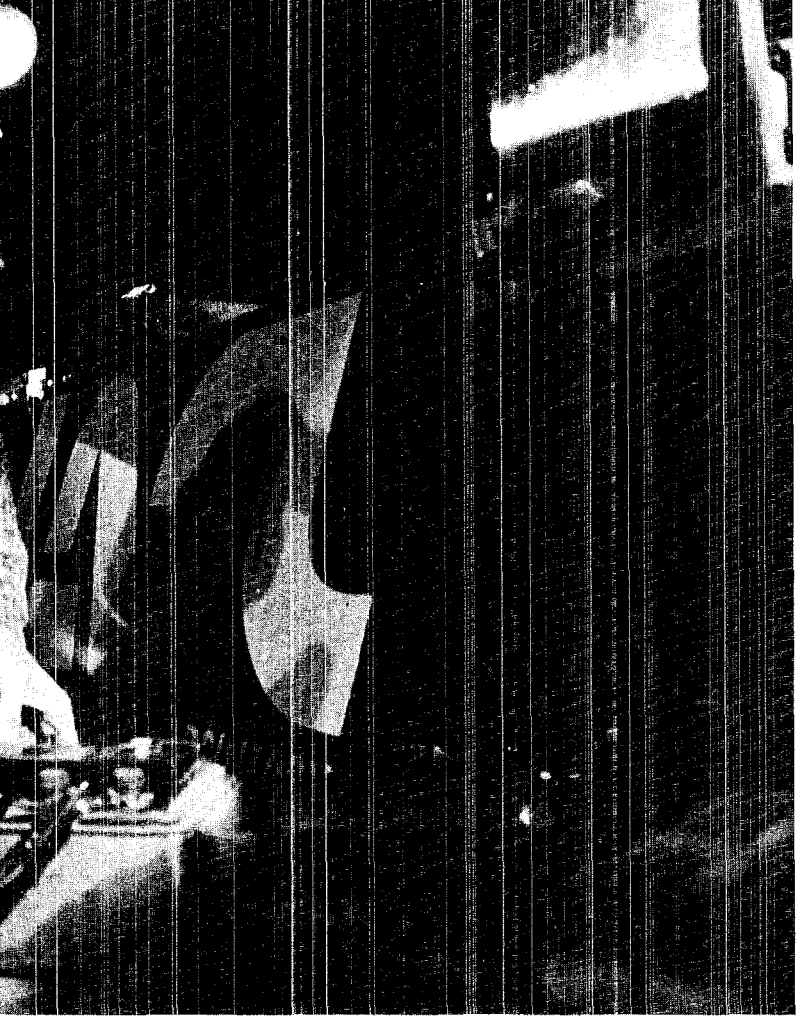
High quality data from the Colony Mine tests, and from further tests, will be the empirical base for developing the computer models for the future.

Mining or *in situ?*

LASL is expected to conduct a third test at the Colony Mine this year, again in cooperation with Atlantic Richfield and Tosco, and again in the range of 200 pounds of explosives — capable of fracturing 400 tons of rock.

Next year, the Laboratory plans at least one large-scale test, although not as large as what would be required in a commercial operation, which is 500 feet on a side by 800 feet high.

By the end of the 1981 fiscal year, LASL will have presented to the Department of Energy a plan for a workable oil shale retort, or extraction system. The *in situ,* or in-place, fracturing of oil shale is crucial to



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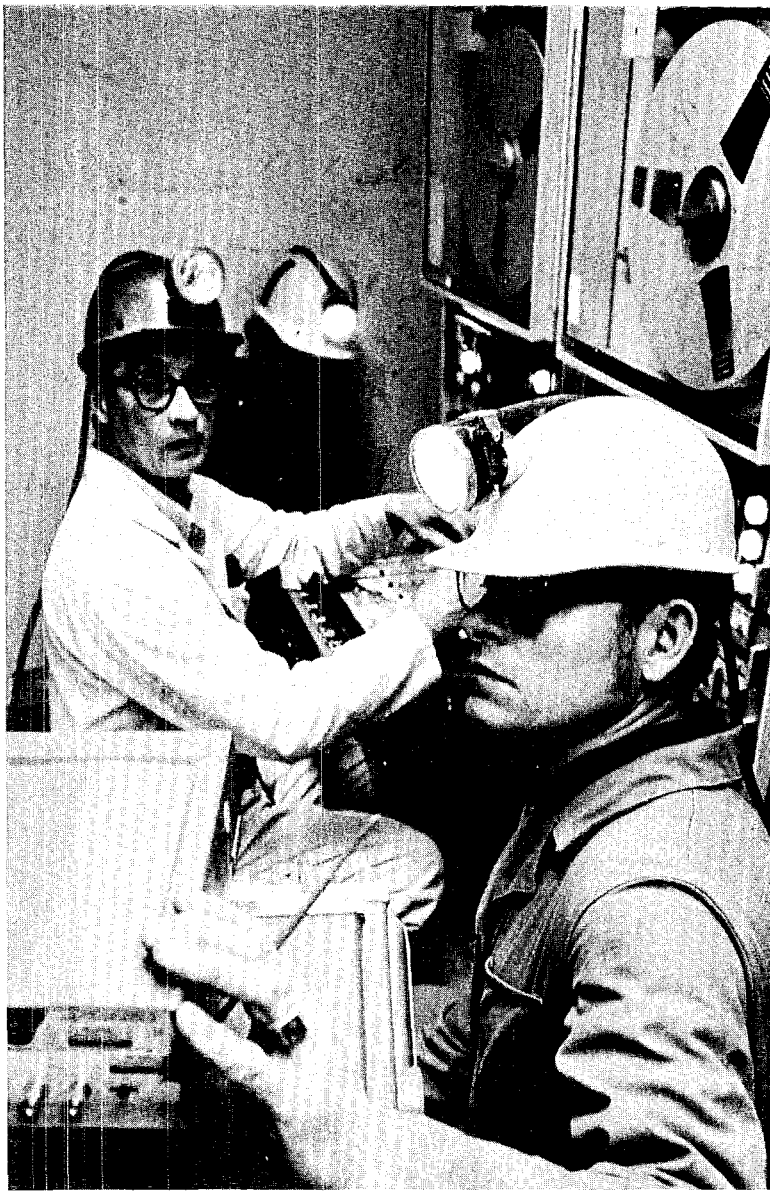


Data were relayed in many ways to the mobile laboratory, located hundreds of feet from the test area in the Colony Mine. Here, researchers checked information gathering instruments.

the success of this "showcase" project.

Some commercial firms have developed ways to coax the oil-bearing material, called kerogen, out of the shale, which is technically marlstone. But these methods have mainly concentrated on conventional mining techniques, bringing the rock to the surface and crushing it and refining it there.

Since only 15 per cent or so of the shale contains oil, the remainder is left as waste to be stockpiled. A view of the picturesque Parachute Creek valley shows how potentially damaging the disposal of tailings could be, if carried out without regard to the environment. If the shale is fractured and processed underground, or *in situ*, much of the disposal problem would become insignificant.

Some of the oil firms have experimented with revegetating small areas of crushed shale, but the Department of Energy is lending weight to the *in situ* process. The LASL tests will help answer the questions of how to fracture rock in a solid volume underground, and will also show how rock responds to blasting in a confined environment.

The explosive, additionally, is cheap. It costs less than a quarter to buy enough ANFO capable of fracturing a ton of shale.

"What we're after," said Carter, "is making blasting a science, rather than an art. This is a new situation that doesn't fit with the older accumulated knowledge of blasting. What's required is a new science."

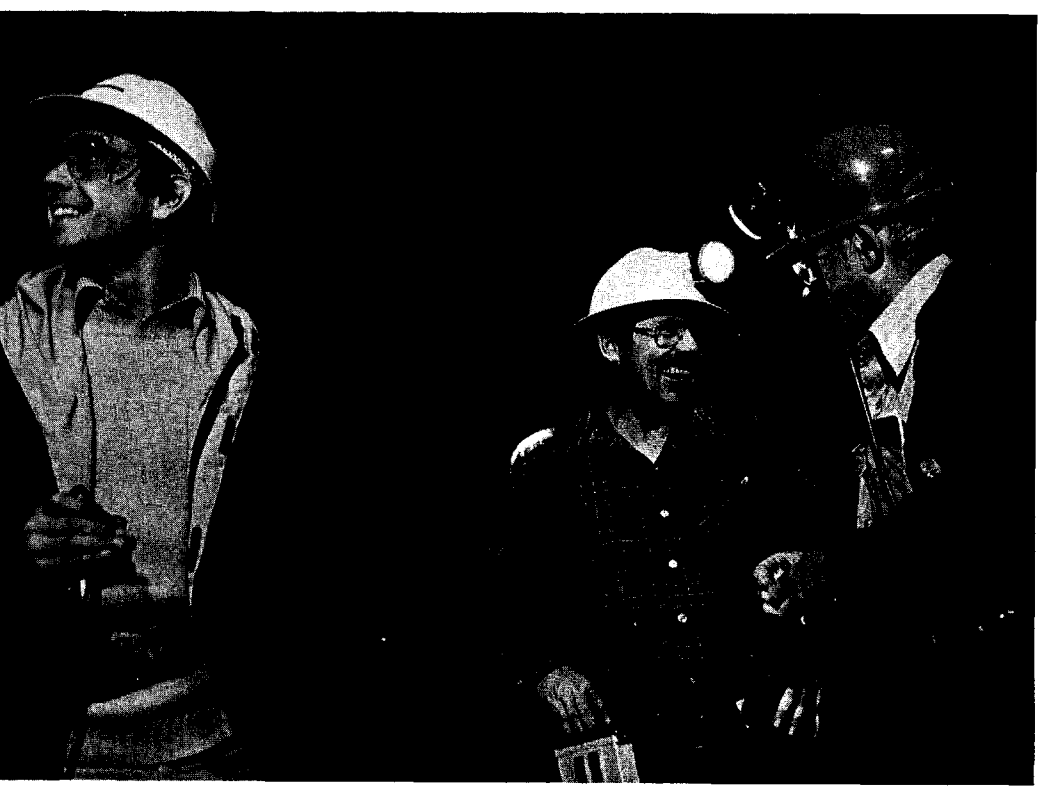
If LASL is able to develop a viable *in situ* oil shale process, above-ground facilities would still be required to refine the product.

Little visible evidence exists on the mine floor after the first explosive test, but LASL scientists were immediately encouraged by what they saw. The rock stayed in place, but long fracture lines extended out in various directions.

Researchers envision fracturing the shale below ground, then heating it, using part of the oil substance itself as fuel. Such a retort could burn for up to a year at 800 to 900 degrees F, breaking down the kerogen, which would be collected as shale oil in an underground sump. From there, it could be piped to the surface and refined into useable petroleum products.

A commercial operation would require the processing of 50,000 barrels per day to be economically viable. The investment in capital would be from $1 billion to $1.5 billion, just for starters.

Oil shale, said Carter, "is not just around the corner. But it is the nation's ace in the hole."



"Success," said G-7 group leader W.J. Carter, left. Agreeing after inspecting the results of the first blast were C.L. Edwards, assistant group leader, and Ki Bianchi, mine captain at Colony Mine.

'This is a new situation that doesn't fit with the older accumulated knowledge of blasting. What's required is a new science.'

Gold contends the earth 'outgasses'

Photo by LeRoy N. Sanchez

LASL host Stirling Colgate (left) exchanged ideas with speaker Thomas Gold (right). Stirling said "the earth burps methane from deep down."

If Thomas Gold's theories are correct, worldwide depletion of hydrocarbon-based fuels could be further down the road than most experts currently predict.

The noted Cornell University professor recently told a LASL colloquium audience that much of the earth's surface carbon is the product of what he calls outgassing. He said the outgassing process could hold the key to the supply of large amounts of fuels in the form of methane gas from deep rock and could aid in the prediction of earthquakes.

According to Gold, constantly generated gases accumulate in the porous pockets of rock deep within the planet. Large pockets of the gases develop and eventually begin to make their way to the surface. He said the gases are released to the atmosphere during natural occurrences such as volcanos and earthquakes. He offered the possibility that outgassing is the cause of some earthquakes.

"In essence," Gold contended, "the earth burps methane from deep down. The gases crack through the mantle, causing an earthquake."

To support his theories, Gold pointed to historical accounts of earthquakes dating back several hundred years. He said the accounts are remarkably similar in certain points which could relate to the release of methane gases.

"According to the accounts," Gold said, "smoke, flames, and fumes were released in a loud report during many of these earthquakes. Many reported the presence of foul smelling, sulfurous gases."

He added that the methane, which in some cases has been found to be 97 percent pure, was ignited easily from static electricity created by dust fanned upward by the escaping gases.

"These eruptions often catch fire; they ignite spontaneously," Gold said, adding that one particular mud volcano released a column of gas that burned upwards to two kilometers. After the initial eruption subsided, the gas burned steadily for two hours from a 100-meter wide mouth and upwards to 500 meters.

"It was the biggest Bunsen burner you ever saw," Gold quipped.

He feels that most of the gaseous hydrocarbons have been formed through the traditionally accepted methods of heat, pressure, and moisture in contact with organic materials which could have been present in the original space material from which the planet was accreted. He said he feels that some of these gases may have led to the formation of coals affecting their conversion at the bottom of sedimentary layers within the earth.

Colloquium host Stirling Colgate described Gold's theory as controversial.

"Tommy's theory will really stand people on end, if it's right," Colgate said, "and is already standing people on end, even if it's wrong."

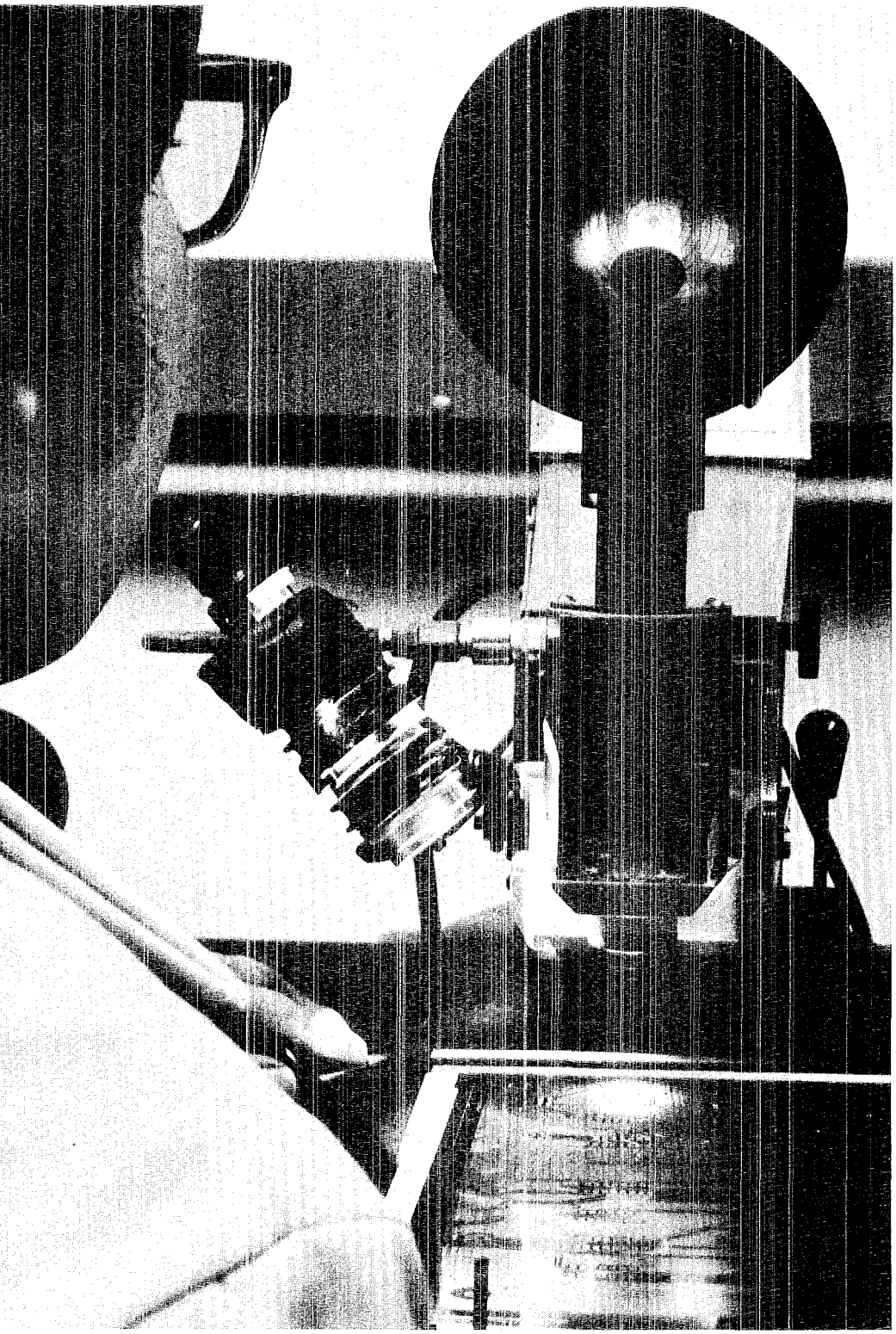
Gold explained that outgassing might occur over a time scale of thousands of years. He added that the high levels of carbon on the earth's surface could not all have been caused by plants or volcanic eruptions.

Gold called for development of "deep seismic prospecting and sounding methods" to aid in plotting the location and size of gas deposits. He said such techniques might enable scientists to predict earthquakes well in advance of their occurrence. Locating a gas pocket would give the added bonus of establishing a source of near-pure natural fuel.

He outlined several areas around the world where gas pockets obviously exist, including the Palmdale (California) bulge. Gold said the California formation probably contains on the order of 10^{10} cubic feet of recoverable methane gas.

When contacted, several LASL scientists said they found Gold's presentation interesting, stimulating, and thought-provoking. Many, however, expressed skepticism with Gold's theory.

— Vic Hogsett



Fermin Romero aligns a printed wiring board by hand under the "old" Uni-Drill machine, which drills hole one at a time. The viewing screen at top right allows the operator to position the drill over each hole location.

Photos by Bill Jack Rodgers

Custom electronics at your fingertips

By Charlie Mitchell

The "Laboratory Activities" book says that group E-2 "makes high-quality prototype and limited quantity electronic assemblies with fast turn-around times not available commercially."

On visiting two sections of the group (Electronic Manufacturing and Technician Service), that statement was found to be an oversimplification. Raul Morales, leader of the printed wiring section, and Leroy Edwards, supervisor of the cable shop, not only offer high-quality products and fast turn-around times; they offer these benefits in an amazing diversity of unique, special request assemblies.

Morales gave a "then-and-now" tour of the printed wiring section. Until this year, all of the printed wiring board made to specifications in E-2 were done by hand.

Manual vs. automatic

One of the more time-consuming operations was the drilling of the sometimes hundreds of tiny holes in the boards that eventually accept the electronic components. The operation required an operator to manually position the board under a light source, which projected the images of the hole locations onto a viewing screen.

As each hole was positioned, it was drilled by a tiny, high-speed drill press. Only three boards can be stacked and drilled simultaneously, and the reproduction from top to bottom is subject to human error. These errors can be minimized and

the production times kept low on small orders. In fact, the manual method may be preferable on one-of-a-kind orders.

The pride and joy of the section, however, is a new $60,000 three-head, air-driven, numerically controlled (AC) drill. Morales said that the accuracy, precision, and speed of the drill, and the number of pieces it can accommodate, make it well worth the price.

Morales, introduced Lee Miller, who is the operator of the drill. At the time, Miller was setting up a tape in preparation for drilling a number of boards.

Using one location as a starting point, Miller moved a viewing scope over the face of a full-sized photographic negative fixed to the drill table. As each hole came under the cross hairs of his viewing screen, Miller activated the keyboard of his computer console.

The computer then punched the location of the hole onto a paper tape and noted the location on a paper printout. Morales explained that this operation is performed only once for each master negative, and that it guarantees one of the chief benefits of the machine — reproducibility.

The tape, so programmed, is fed into a reader during the production run. As many as nine boards per panel can be set up in the drill table for drilling. After the location of the "starting point," three air-driven drill heads simultaneously and automatically drill all of the holes required under direction of the paper tape — at 30,000 to 54,000 rpm.

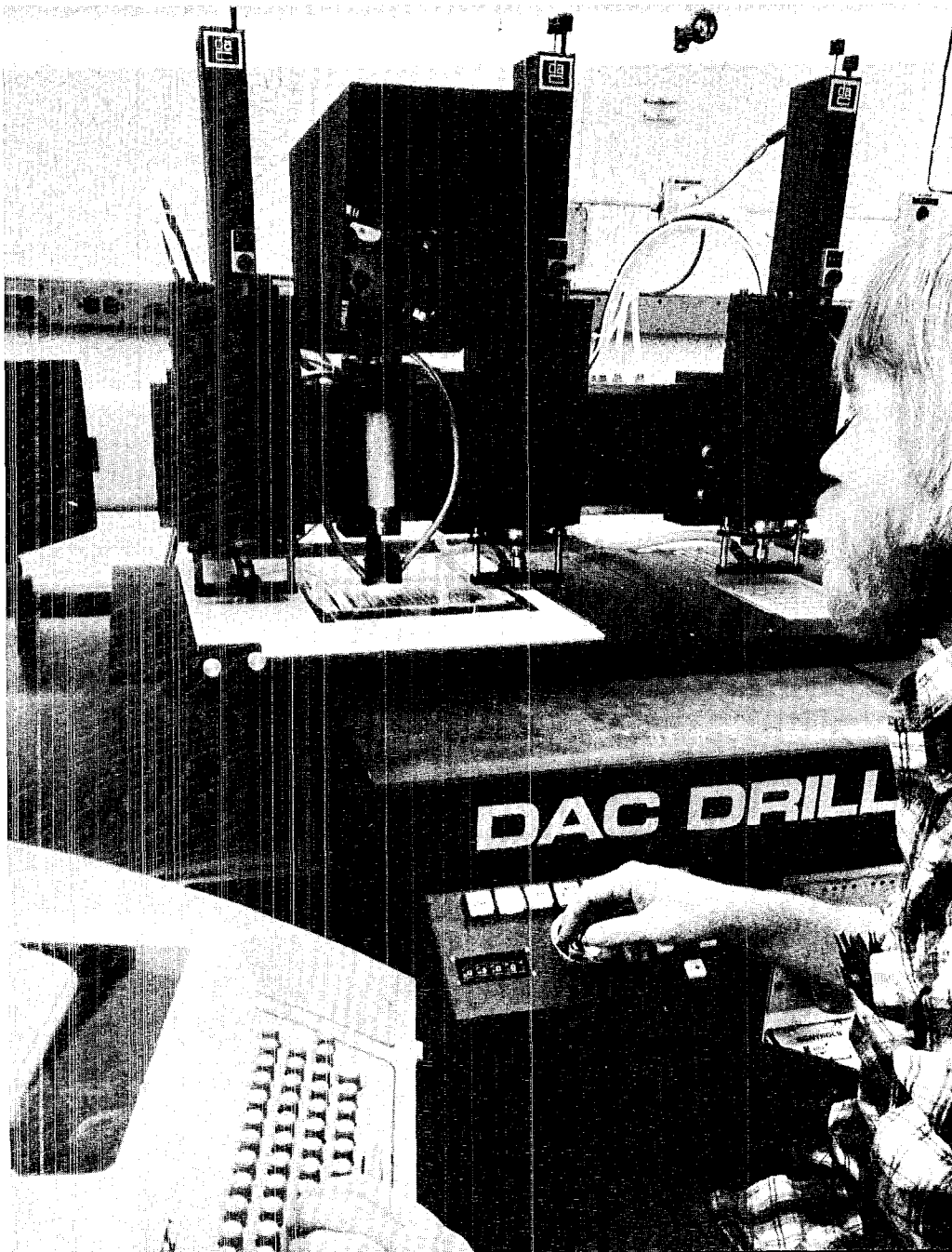
Lee Miller prepares the punched paper tape that will guide the "new" drill during manufacturing operations. The viewing scope and screen (top center) is positioned by the "joy stick" at console just over Miller's right arm. The hole locations appear on the readout screen above the keyboard; they are printed simultaneously on the typewriter. A master negative is in place under the viewing scope. Above it at rear are three drill heads.

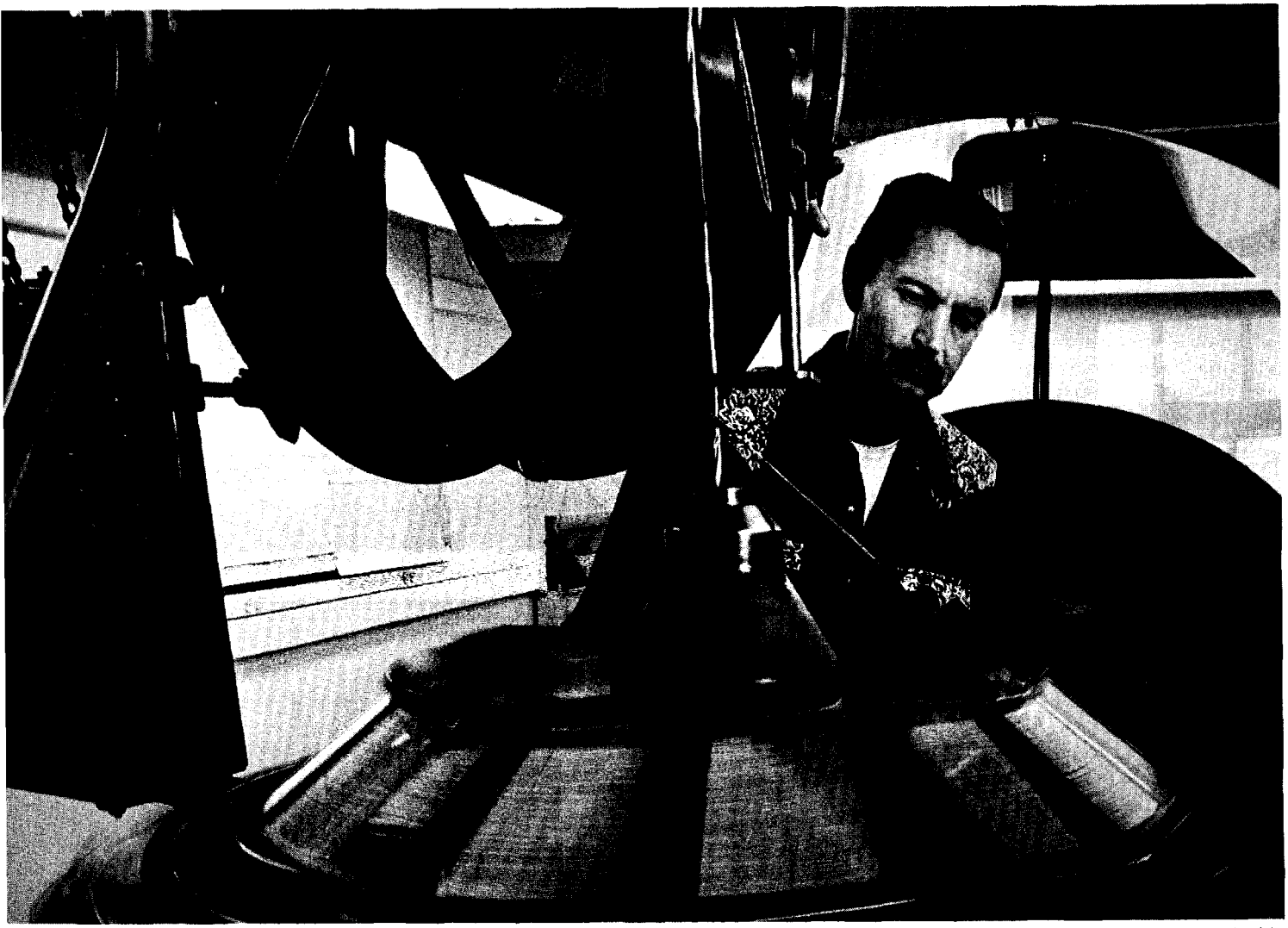
Wiring boards and special cables can be custom made by E-2. The 'pride and joy' machine is a new $60,000 drill that is keyed to a computer and uses a master negative.

In addition to the hole-drilling operations, the NC drill will also rout, or cut out, the boards, although it will not cut curves or circles. All of these operations can be done with a precision of ±.003 of an inch.

The section is now involved in a study to determine how the new drill is to be integrated with the remainder of the circuit board manufacturing operations, so that the flow of work will be smooth and rapid. They want to ensure that they can maintain their excellent turn-around times from initial order to completion, and that no bottlenecks will develop.

Morales said that the drill will not likely be used for orders of less than 10 pieces. He anticipates that orders will generally run in the 20 to





A 20-spool machine at right feeds cable elements to a braiding machine. In the center, cable is being wrapped with tinned copper wire before it is wound onto a reel. Twist in the cable—an important element in design and function—is determined by the turning speed of the spool machine.

50 piece range. As has always been the case, this will not be a "production" operation. All of the pieces to be made will be unique to LASL and not attainable from industry on a reasonable time scale.

With the continuing and increasing use of the printed circuit in electronics, this updated capability in E-2 will ensure that the staff at LASL will be able to obtain good quality custom circuit boards, quickly and relatively inexpensively.

Custom cables

Leroy Edwards' cable shop at Two Mile Mesa could not be more different from Morales'. The cable shop uses materials in stock from many manufacturers and turns them into products unique to LASL's requirements.

In fact, Edwards said that they keep in stock 50 different cable assemblies that they've made for various Laboratory applications. Cables of any length, up to one inch in diameter, and having as many as 20 pairs (40 wires) may be twisted, braided, and wound on reels in one operation. Both the amount of twist, and the density of the braid, are variable.

The equipment to perform these operations is a hybrid. It consists of a commercially available braiding machine called a "24 carrier unit" and a wire-dispensing device designed and manufactured by E-2.

The commercial unit holds 24 bobbins of tinned copper wire, and braids this wire around the cable as it passes through the machine. The E-2 ancillary machine is essentially a rotating spool holder that imparts the desired twist to the cable material. Up to 40 kinds of wire or packing can be twisted on this machine.

Edwards said that the twisted cable is overlain with the metal braid both for strength and electrical shielding. The density of the braid is expressed in "picks per inch" and varies from very open to very tight spacing. The cable shop hopes soon to add fiber optic cable fabrication to their product line.

Leroy Edwards holds a selection of cables made in E-2's cable shop; some of the many available connector ends are also shown.

The cable shop keeps in stock 50 different assemblies that have been made for Laboratory projects. In one operation, cables up to an inch in diameter and having up to 40 wires may be made.

Edwards' section not only manufactures custom cables, but will fit them with the proper connectors. Many of these connectors are kept in stock at the cable shop. Special connectors may be ordered to the customer's specifications.

Group E-2 is continuously modernizing so that they can supply the needs of the Laboratory. The electronics services group is truly living up to its name.

Chamber to study muon decay

Often it seems that, once a law is established, someone soon will become bent on breaking it. Such is the case with four members of the Nuclear and Particle Physics group (MP-4) who are studying rare decay modes of the muon. The quartet, consisting of Minh-Duong Van, John Sandoval, Charlie Dalton, and Roger Carlini, has assembled the world's first frameless cylindrical drift chamber. With any luck at all, the instrument will allow them to observe a one-in-a-trillion event which could send the lawmakers back to the drawing boards.

According to Van, theoretical calculations show that every once in a while a muon particle will decay into three electrons, or it will decay into one electron and two gamma particles.

"If we can observe the decay," Van said, "it will mean the current accepted gauge group is not large enough to explain the laws of weak interactions. It will cause added research to explain the phenomena."

Observing a trillion decay modes in an attempt to find one specific event is pretty touchy business requiring some sophisticated instruments. Seemingly, observation of the proposed decay would make finding a needle in a haystack look like finding an elephant in Ashley Pond. Sandoval likens the drift chamber to a screen against unwanted decay modes.

"It will allow only the observation of the desired decay," he said. "It will not detect any other type of decay."

To accomplish this, the MP-4 researchers have taken pains to bend the odds more in their favor. The reasons may be obvious.

"When you have something that happens one in 10^{12} times you don't want to miss it," Dalton explained.

For this reason, Van added, it was necessary to design a frameless device.

"If we had any frame whatsoever," Van explained, "multiple scattering would decrease efficiency by the third power."

Dalton noted that a frame would cause deflection of a particle. He said, "It could be the particle we're looking for."

Copper-beryllium sensing wires are integrated in the device at a stereo angle to provide additional points of reference for spotting the desired decay. Dalton explained that if the wires were placed only in parallel, it would be possible for particles to produce confusing signals. He said copper-beryllium is necessary because of its special properties of high elasticity.

Once in place in the Clinton P. Anderson Los Alamos Meson Physics Facility (LAMPF) muon beam line, the drift chamber will be encased in a module surrounded by scintillators, and 400 blocks of sodium iodide for total energy measurements.

"LAMPF is one of the few, perhaps the only place in the world where such an experiment is possible," Van said. "It has the world's highest intensity muon beam.

"Other facilities have high-energy, but low-flux, beams. LAMPF is just the opposite. It makes it ideal for us. This is all due to the farsightedness of such people as Louis Rosen (MP-Division leader) and Darragh E. Nagle (MP-4 leader)."

Van also had praise for the LAMPF technical staff, saying the drift chamber worked the first time it was turned on. Dalton seconded Van's feelings and added, "With cleanliness, gas mixture and pressure—there are so many variables that can cause the chamber not to work right. It's pretty rare for a device of this type to function on the first try."

—Vic Hogsett

This frameless drift chamber was constructed to detect a one-in-a-trillion event. Here, from left, Charlie Dalton, Minh-Duong Van, and John Sandoval examine the chamber before it is placed in the muon beam line of the Clinton P. Anderson Los Alamos Meson Physics Facility.

Photo by LeRoy N. Sanchez


UNM

Explosion welding

Before two metal plates are joined with explosion welding, laboratory preparations are made. Here, Alex Popoff (center), together with Patrick Rodriguez and Earnest Morris of group CMB-6, check the alignment of the two plates. The upper, or flyer, plate has been attached to a plywood box and the lower, or base, plate has been attached to a plywood sheet.

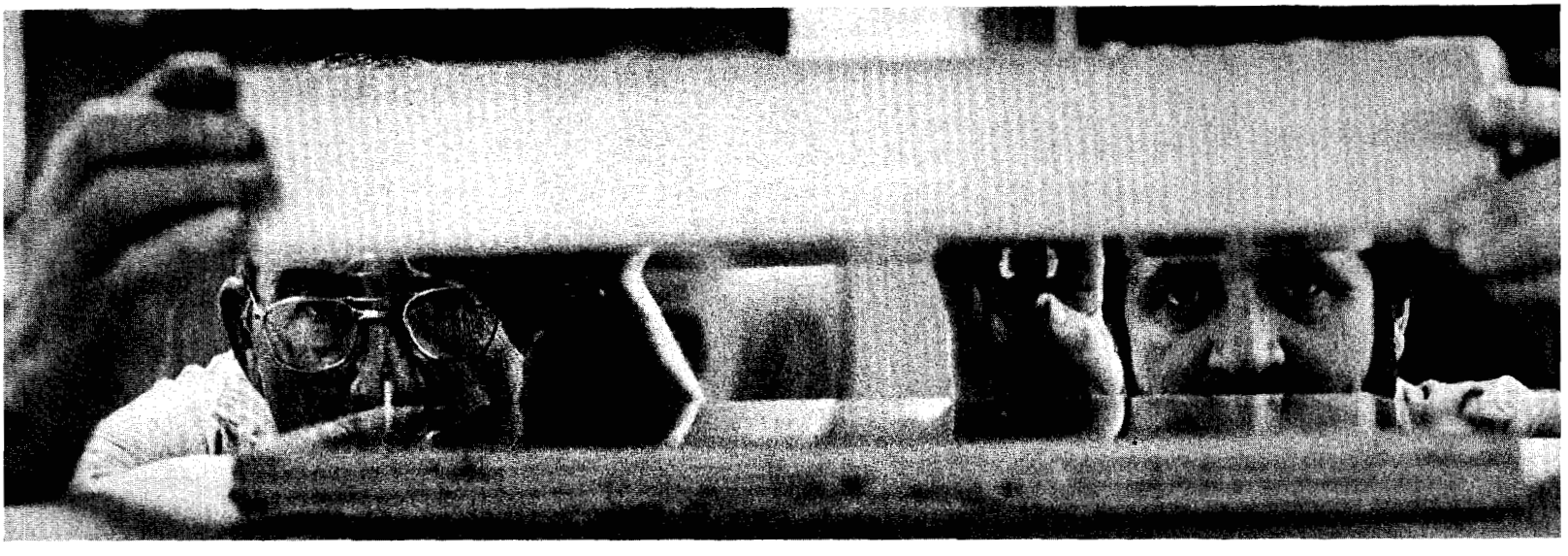
By Jeff Pederson

"In the early days, when we told industry people they could weld metals with explosives, they would just smile politely," said A.A. Popoff, a staff member in Group WX-3 of the Design Engineering (WX) Division.

Times have changed since the early 1960s, when Popoff worked at DuPont as a participant in the pioneer days of explosive welding. The process, whereby one metal plate essentially is driven into another at speeds below that of sound, is now commonly used in industry. It may, however, still be novel to the layman.

Sandwiched coins

An early application of explosion welding was the manufacture of the first batch of sandwiched coins used in the U.S., after the "solid" quarters, dimes, and half dollars received their death notices. DuPont made



Morris and Popoff recheck the standoff distance between two metal surfaces. Pins at the corners of the assembly will keep the plates apart at a uniform distance until the explosive is detonated.

Photos by Bill Jack Rodgers

the 3-layer coins, using copper-nickel alloy plates (22 millimeter) on either side. In the center was a 114 millimeter copper cake. The welded composite was first broken down by a hot rolling process, then cold-rolled to the proper thickness and shipped to the U.S. mint for coining. Our laminated coins are now fabricated using a more conventional rolling process.

Other applications of explosion welding offer savings in materials, because only a minimum layer of a costly metal need be applied on a less costly lower layer, or substrate.

In addition, the bond created by this type of welding is almost always stronger than any of the metals involved. This weld between dissimilar metals allows a welder to use a bimetallic plate as a transition joint. Conventional fusion welding can then be used to join similar metals on both sides of the joint created by explosion welding.

Before the days of explosion welding, certain bimetallic combinations, such as tantalum-steel and titanium-steel, were not available in plate or sheet form. They certainly were not available in commercial quantities. Where one would expect failure of a certain metal in certain situations, such as bonding tungsten to aluminum, explosion welding can prove successful.

"Los Alamos is an ideal place to practice explosion welding," said Popoff, a mechanical metallurgist by training who has been at LASL six years, and who has authored several basic patents and technical papers related to the field.

"We have readily available test sites and metal assembly areas, and facilities for metalworking, such as hot and cold rolling; deep drawing; and other forming techniques," he added.

Welding theory

Simply put, explosion welding involves the placement of two or more metal layers, spaced apart at precisely measured distances. Explosives may be contained, typically, inside a plywood box positioned on top of the upper plate, called the flyer plate. The lower metal is called the base plate.

When the explosion occurs, a detonation front moves linearly. This causes the two metal plates to impinge; the angle is determined by the separation distance between the plates.

A re-entry jet of metal is formed at the high pressure collision point, and runs ahead of this point. This effaces the colliding surfaces, and welding results as some of the jet of metal is trapped and solidifies.

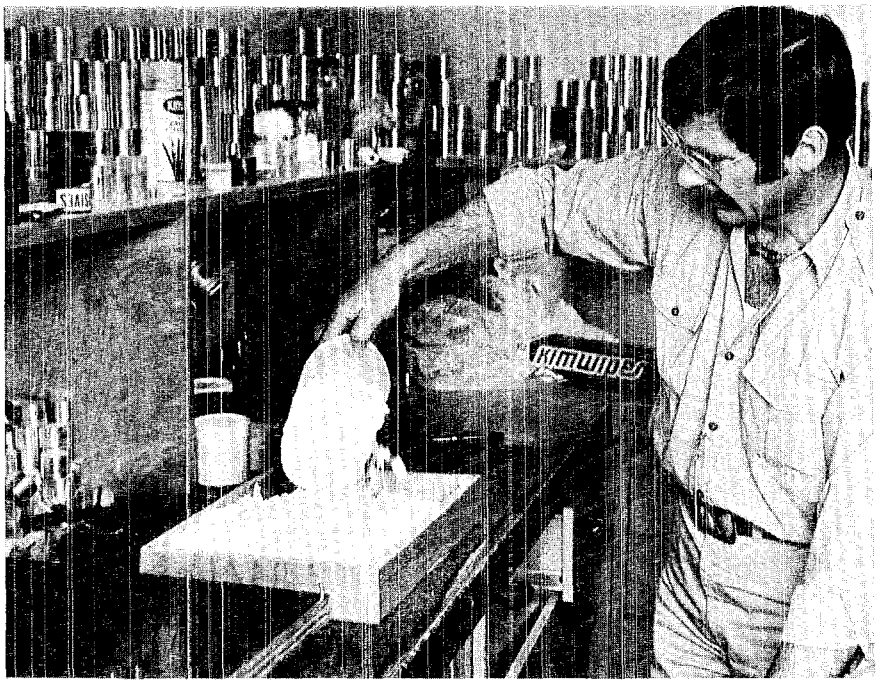
The rapid solidification rate required for the new bond is about one ten-thousandth, or 10^{-4} seconds.

People who work with explosion welding look for a wavy pattern in the resulting joint, when viewing a cross section. The waves increase the surface area of the interface.

Jetting can occur at subsonic, sonic, and supersonic velocities, said Popoff, but higher speeds mean undesirable shock waves can occur. This can cause damage to material so, in practice, explosion welding is carried out at collision velocities much lower than the sound velocities of the metals.

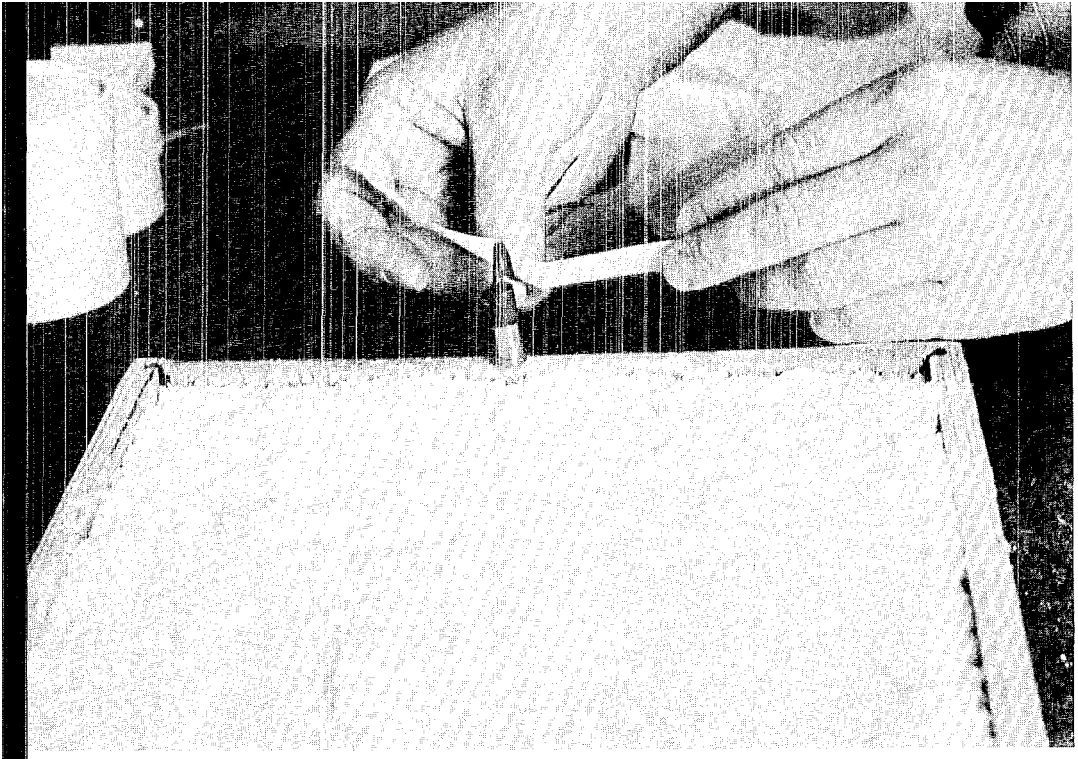
Explosives

Explosives are available in gaseous, liquid, and solid forms. The detonation velocity of an explosive is proportional to its density, while the pressure generated during a blast is proportional to both density and velocity.

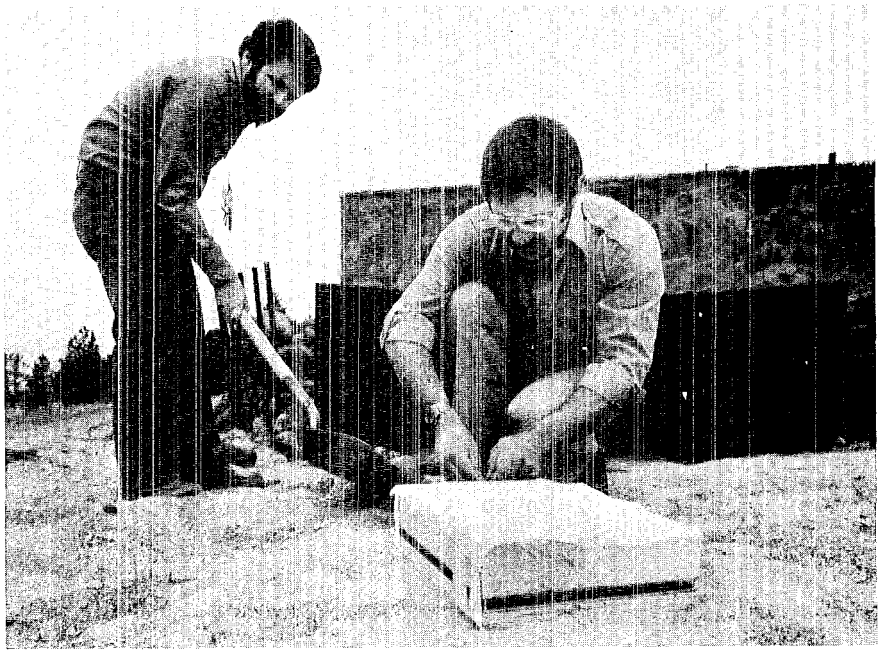


A powder explosive is placed into the plywood box atop the upper metal plate. The base plate is in foreground.

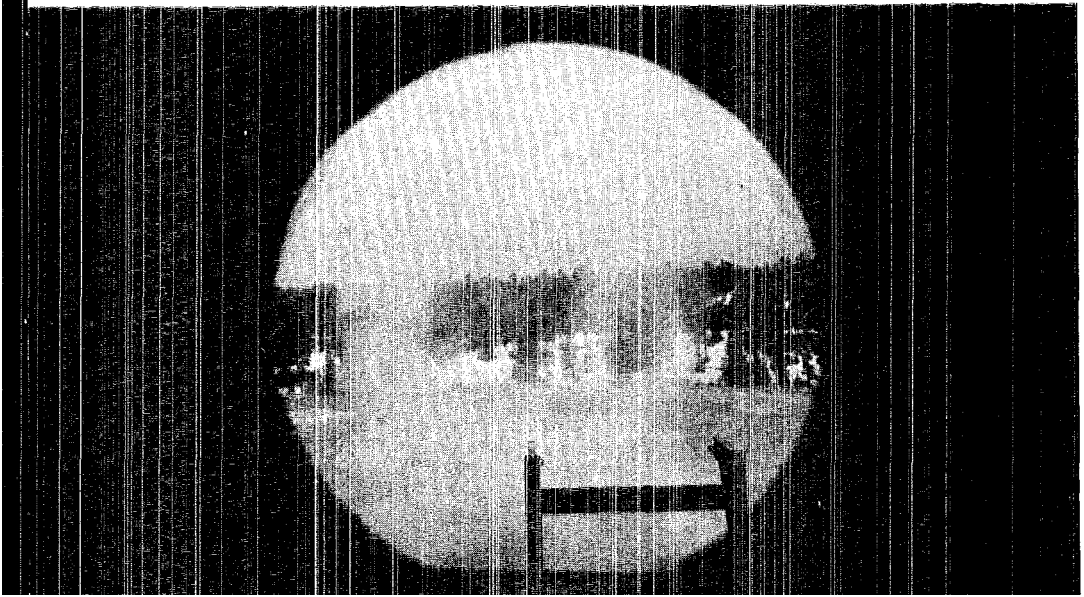
One metal plate is driven into another in the explosion welding process. An early application was the first batch of sandwiched coins used in the U.S.



An explosive cap is placed at one end of the plywood box after the explosive is in place. The detonation front will move from the cap toward the other end of the box; welding will take place between the metals along this path.



At S-Site, Popoff and Rodriguez place the metal assembly, with explosive at the top, at a safe shooting location. A protective bunker is in the background. Trailing wires are covered with earth.



A cloud of dust is raised when the explosive is detonated from the protective bunker. This view is through a viewing port.

Compositions used successfully in explosion welding, to name a few, are: ammonium nitrate prills; flacked TNT; nitroguanidine; PETN-based rolled sheet; and amatol and sodatol diluted with rock salt. Explosives in a powder form have generally proven to be the most practical and economical.

Good shooting sites outside of LASL's remote technical areas, said Popoff, would include quarries, mines, or wooded valleys.

Testing the continuity of a bond is best done with ultrasonic inspection and with destructive analysis. The best welds are obtained using easily moldable metals and alloys that are metallurgically compatible. Nickel or nickel base alloys, allied with steel, and stainless steels welded to steels, are good examples. Only beryllium has continually been a problem metal.

LASL projects

Many useful explosion welding projects have been undertaken at LASL, said Popoff, who has shot off some 155 tests in three years to meet Laboratory requirements. The shots have involved both transition joints and bimetallic sheets where dissimilar metals have been welded and now are part of assemblies here:

— A tritium ion source for the Intense Neutron Facility was fabricated using a transition joint;

— A superconducting test loop was made for the Energy (Q) Division, using a niobium-titanium superconductor that was welded to copper;

— A liquid scintillator for PHERMEX was formed, using a bonded and cold-rolled laminate of copper, tantalum, and copper;

— A fuel element body for a device was shaped for use in a sodium-cooled test reactor loop. The transition joint used consisted of a copper-manganese alloy sheet welded on both faces to sheets of tantalum;

— A high-temperature window was fabricated for an Air Force laser, using a niobium-iron-Inconel 600 transition joint;

— Special clads of vanadium-copper, and vanadium-molybdenum, will be evaluated by Sandia Laboratories to see if they can be used as limiters on a controlled thermonuclear reaction project;

Many useful projects have been undertaken at LASL in the last three years. Some 155 tests have been shot by Popoff to meet Laboratory requirements.

After the blast, Rodriguez and Popoff check the results of the work. The plywood attached to each metal plate has disappeared, leaving only some glue marks. The metals are joined.

'It is still an esoteric process. It is an art to weld with this stuff. The theory will probably never catch up with the practice.'

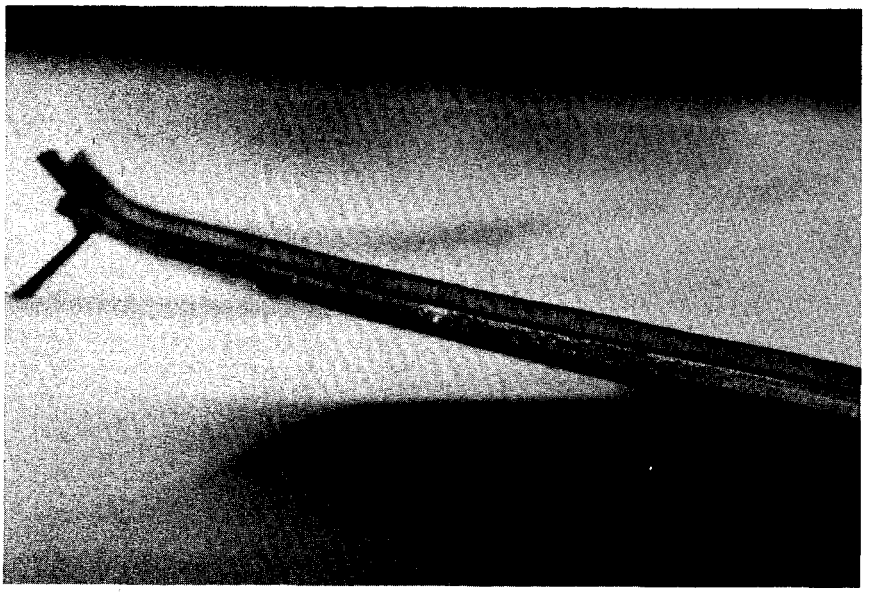
— And, as a "crowning achievement," Popoff notes that an explosion welded transition joint went downhole in the physics package of a nuclear device at the Nevada Test Site in 1979.

It has also been demonstrated at LASL that a metal that is not ductile at ambient temperatures may be welded with explosives if the assembly is first heated. As an example, a tungsten-stainless steel assembly was heated to 500 degrees C before applying the explosive.

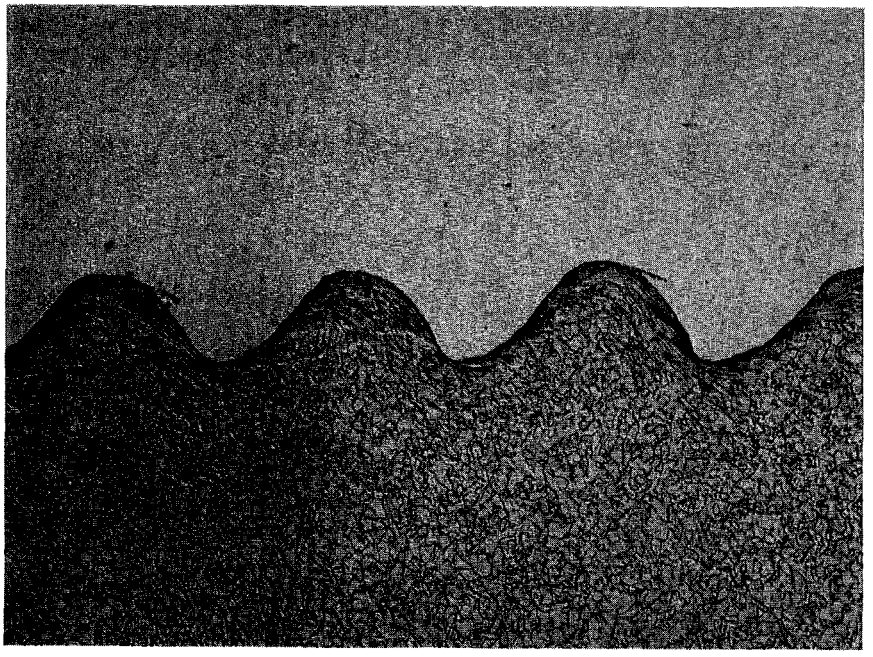
Explosion welding becomes more economical when one of the metals involved is expensive. Tantalum, for instance, costs more than $60 per pound, and steel costs less than $1 a pound. A thin layer of the tantalum easily welded over the less expensive steel base is attractive to industry. Also, in a world of diminishing and scarce resources, the use of clad metals becomes a real conservation measure.

"I like to think of explosion welding as being tied to other metalworking processes such as hot- and cold-rolling," said Popoff. "This way, thicker and smaller assemblies may be welded and existing equipment may then be used to arrive at the desired thickness and area. This is really the reason that a metallurgist has an appropriate background to work on explosion welding.

"It is still an esoteric process," he added. "It is an art to weld this stuff. The theory will probably never catch up with the practice."



Jetting, caused by the explosive, has created a joint between the two plates that is stronger than either metal. A spacing pin at one corner remained after this shot.



This micrograph shows in detail a weld cross section, with distinctive wavy pattern caused by the detonation front. Here, a sheet of type 304 austenitic stainless steel was welded to a plate of carbon steel. The magnification is 100 times.

Short subjects

Scientists at LASL and other agencies have responded to the need to study reported attacks on the earth's ozone layer. In 1974, two researchers at the University of California, Irvine, predicted that halide compounds (fluorine, chlorine, and bromine) were being transported to the stratosphere as Freons released from aerosol spray cans. Concerns were raised that crop destruction and increased numbers of skin cancer could result. New methods to measure the halides, including a sampling technique capable of measuring one part in a trillion, were developed. High flying aircraft and balloons gathered samples, verification was given, and the use of Freons is being reduced.

* * *

"Lasers and Your Eyes," a new 16 mm color film on the hazards to your eyes from lasers, is available for short loan from LASL. The film runs 13 minutes and was produced by the Motion Picture and Television Group (ISD-9). The movie describes the basics of simulated emission of solid and gas lasers and the hazards to eyes if proper protection is not used. It can be obtained by calling the classified report library, 667-4446. It may also be purchased for $130 from Cinesound in Hollywood, California.

* * *

Scientists and engineers have developed two new portable radiation monitors that are smaller but more sensitive and longer-lived than existing instruments. The monitors have been designed in a collaborative effort between the Health Research (H) Division and the Electronics (E) Division. One device warns, with beeps, when exposed to low levels of radiation. It is called the Wee Pocket Chirper and can be clipped to a shirt collar. The other, called the Wee Pee Wee, has its electronics built into a small package that is affixed to the back of a standard alpha particle detector. It is portable and lightweight and can be operated with one hand. Instruments based on its design are already being marketed by two commercial vendors.

* * *

The first regularly scheduled public tour of the solar modular homes at LASL took place April 7. The tour will be expanded May 5 to include the solar laboratory and testing station, in addition to the two homes, one of which uses a passive system and one which uses active collectors. Scheduled tours of the meson physics facility (LAMPF) are usually held the first Saturday of each month, and Laboratory visitors may visit that accelerator and then go on the same tour bus to the solar homes. Reservations must be made with the Public Relations Office (PUB-2) by calling 667-4444.

* * *

A cooperative welding training facility has recently been opened; it is a joint venture of LASL and the Zia Company to train technicians and craftsmen. Located on 7th Street near DP Road, the facility was set up at the request of several LASL divisions where a variety of welding techniques are in demand. About 40 students have taken one or more of a series of mini-courses offered in 10 areas of study. The courses range in length from three weeks to 36 weeks. Enrollment is handled through the LASL training office (PER-5). About 100 employees have already applied for courses.

* * *

Los Alamos and other national laboratories have been told by the Department of Energy to reduce natural gas consumption by 50 percent by 1985, and to eliminate the use of this fuel by 2000. LASL's projected use of natural gas in fiscal year 1979 is 2.87 million BTUs. Department of Energy officials have directed the development of conceptual designs for a geothermal heating plant and for a coal-fired plant that would generate electricity and bleed off lower temperature steam for direct space heating. Laboratory officials, however, are concentrating on studying the feasibility of using geothermal energy to heat LASL's 4.5 million square feet of facilities. A coal plant, they point out, would have a negative environmental effect and would require one 20-ton truck load of coal every hour, year around, to meet the Laboratory's needs. Some help is expected from solar energy, with up to 35 percent of the heat in new facilities coming from the sun.

* * *

Science Youth Days were observed at Los Alamos for the twenty-second year. High school students from schools in four states arrived here April 5 and 6, with April 4 set aside for Los Alamos High School. The 800 participants were invited by LASL and are generally science-oriented. Those from larger urban areas are selected through competition in their schools. Students heard lectures on the meson physics facility; lasers; and the hot, dry rock energy program. They also toured technical sites. Science Youth Days were begun to honor inventor Thomas A. Edison.

* * *

10, 15, 20 years ago

10 years ago

World's largest safeguards program

Recognizing the need to control internationally the use of atomic materials and processes, the Atomic Energy Commission established a new safeguards program in 1967. The largest research and development project in the world was centered at Los Alamos, with laboratories at Pajarito Site and Ten Site. Physicist G. Robert Keepin was named to head group N-6, created to carry out the program.

Project Rulison planned

LASL is responsible for designing and developing the nuclear explosive for Project Rulison, scheduled for western Colorado. Laboratory representatives have been at the site, 40 air miles northeast of Grand Junction, for weeks. The experiment is to see whether natural gas production can be stimulated underground.

Employment increase for lab

A projected increase in LASL employment of 150 persons in the next two years was forecast, although a cut in K-Division was also revealed. A $900,000 cut in funding for the reactor division will mean a staff reduction of about 12 men, said LASL officials. K-Division receives its money from the Atomic Energy Commission's division of reactor development and technology.

15 years ago

Hot run set for Kiwi B-4D

The Kiwi B-4D reactor is being readied for a "hot run" at the Nuclear Rocket Development Station in Nevada. It will be the first such test of a Project Rover experimental reactor since November 30, 1962. Since then, a series of cold flow experiments have been performed and new designs in the core support structure and a seal have been incorporated into the new model.

Sundts headed for oblivion

Shed a tear for the Sundt apartments. After many false starts, they are headed to the scrap heap. When they were completed in November, 1943, at a cost of more than $2 million, an optimistic Army official said all foreseeable housing requirements had been fulfilled at Los Alamos. He was off by a factor of 10. Now, as fast as each building becomes vacant by attrition, it will be boarded up or torn down. Originally, there were 74 buildings; they were heated with coal or wood the first several years.

End of the old technical area

TA-1, where once the world's top physicists and metallurgists worked frantically to prepare the first nuclear weapons, moved to the brink of extinction this week. Jim Taub, CMB-6 group leader and a LASL pioneer, pulled a switch that shut down the hot press in the "old Sigma" building. This last portion of the old Main Technical Area is what's left of the hodge-podge of frame, block, and metal buildings that once reached east to the standby power plant and sprawled across Trinity Drive to curl around Ashley Pond in downtown Los Alamos.

Oppenheimer welcomed back

A capacity crowd gave J. Robert Oppenheimer a "warm welcome back" at the Civic Auditorium in his first public appearance in Los Alamos since leaving as LASL Director, a post he held from 1943 to 1945. Oppenheimer, 60, received a standing ovation from more than 900 persons who attended his talk on the late Danish scientist Niels Bohr. Oppenheimer said quietly he was "very deeply moved by the warmth of your welcome, and glad I could be here tonight to talk of all of our pasts, and of our futures."

20 years ago

INSANE project planned

George Cowan of J-11 has been put in charge of the steering committee for Project INSANE. It started with a group of scientists proposing a meeting for "Scientific Applications of Nuclear Explosions," or SANE. Someone thought it could be called "Industrial Applications of Nuclear Explosions," or INANE. Another thought was, "The Industrial and Scientific Applications of Nuclear Explosions," or INSANE. At any rate, the meeting is set for July and will include representatives from other national laboratories in roundtable talks.

Milk studies featured in hearings

Findings of a LASL study of radioactivity in milk and in humans form the basis for Congressional testimony this week in Washington. The topic is fallout from nuclear weapons tests; our presentation was prepared by Wright H. Langham and Ernest C. Anderson of H-4. Now in its fourth year, the LASL program measures a radioactive fission product, cesium-137, in people and in the milk supply of the U.S. and some foreign countries. Samples are received each week and measured in the "human counter." The cesium content of humans has shown a definite correlation with milk from the area in which they live. It remains far below the maximum permissible dose.

Culled from past issues of the *LASL Community News*, the *Los Alamos Monitor*, and *The Atom*.

Solomon Buchsbaum, chairman of the study group appointed by the Department of Energy to examine the relationship between the University of California and the two laboratories it manages for the DOE, fielded reporters' questions following an open hearing here March 20.

Photo by LeRoy N. Sanchez

Gov. Pete Concha was one of the northern New Mexico community leaders who attended an annual buffet and reception at the Laboratory early this spring. The gathering, hosted by the LASL Director, was aimed at informing governmental leaders about the work done in Los Alamos.

Photo by LeRoy N. Sanchez

Among our visitors

Students from Lovington, New Mexico, were among the nearly 900 high school participants in Science Youth Days during the first week of April. Here, they viewed the blue glow of the water-encased core at the Omega West reactor.

Photo by LeRoy N. Sanchez

Edmund G. Brown, Jr., governor of California, paid a surprise visit to Los Alamos in late March to familiarize himself with some of the research programs here.

Photo by Bill Jack Rodgers

Glen Carter and Chet Kazek of C-5 observe stalagtites that have grown from the ceiling of an office room in the Computer Science and Services (C) Division. The stalagtites were formed as moisture atop the building penetrated the roofing material, then leached down through a layer of pumice insulation and found an outlet in a crack of the cement slab ceiling. Precipitates, probably from both the pumice and the concrete, formed the growth. The Engineering (ENG) Department said that bids to fix roofs at Buildings 123 and 200 were being let in April; repairs should be underway by mid-May.

Photos by Bill Jack Rodgers